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2010

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Preface

This work was done within the SELTRA project, which was carried out with the financial support of the European Union and the Danish Ministry of Food, Agriculture, and Fisheries.

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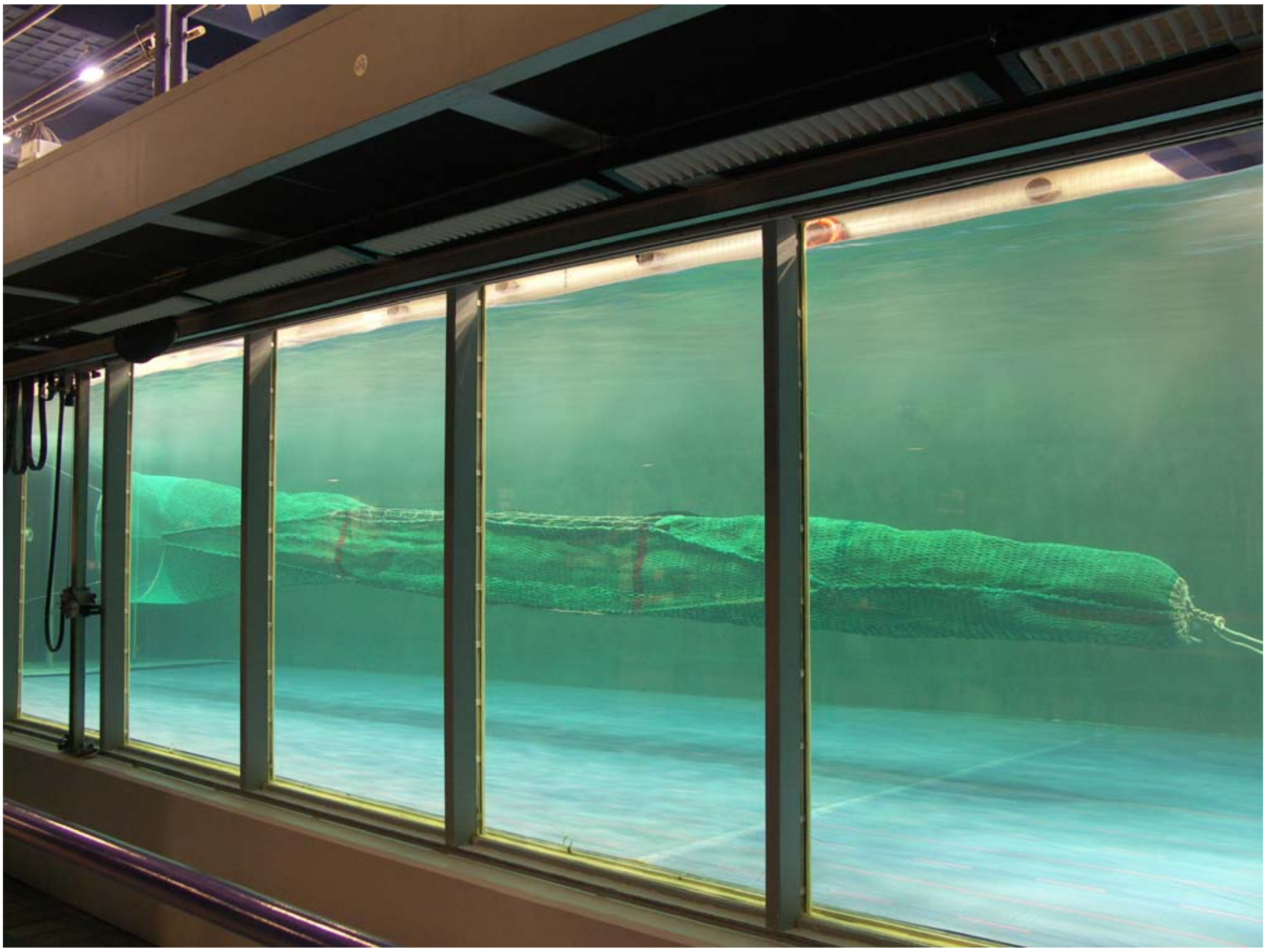

Summary

A substantial improvement in the gear selectivity with respect to cod (*Gadus morhua*) in the Kattegat Norway lobster (*Nephrops norvegicus*) trawl fishery is urgently needed to support rebuilding of the depleted cod stock. The escape windows currently in use are not efficient enough at releasing cod. To address this issue, we developed a sorting box using new concepts aimed at improving the escape of cod through an escape window while retaining the catch of Norway lobster being the most economical important species in the area. The sorting box can be applied to most demersal trawl types, and the concept can be used in other areas and fisheries where similar problems are often experienced. We compared the selectivity of the sorting box to that of a nominal 90 mm standard codend, without selective devices, and to the theoretical selection curve of a 120 mm standard codend. The sorting box greatly reduced the cod catch. The mean selection curve did not indicate a loss of Norway lobster, but the variance was relatively large. The escape window also had an effect on the catches of flatfish and other roundfish species. A modified version of the sorting box concept was implemented in the Kattegat fishery from 2009.

Introduction

The Atlantic cod (*Gadus morhua*) stock in the Kattegat is at a critically low level (ICES, 2009), and actions have been taken to rebuild the cod stock. These actions include the designation of areas that are seasonally protected (beginning in 2009) and where the use of very selective devices is required.

Because Norway lobster is the major target species in the Kattegat, relatively small codend mesh sizes (90 mm) are used compared to the codends (120 mm) used in the whitefish fishery in the North Sea. The consequence is a relatively high bycatch of small cod and high discard rates (Krag et al., 2008; Frandsen et al., 2009). Use of a sorting grid is an option in the legislation. Sorting grids are very selective with regard to letting cod escape (Valentinsson and Ulmestrand, 2008; Frandsen et al., 2009), but they are more difficult to handle from the small vessels operating in the area, and fish and debris can block the grid. Furthermore, loss of Norway lobster, particularly the larger and more valuable individuals, has been observed (Frandsen et al., 2009). The square-mesh escape window (henceforth window) is one of the most used selective devices in European fisheries. A 120 mm window (henceforth window) was implemented in the Kattegat and Skagerrak fishery beginning in 2005 (Krag et al., 2008), but it produced no marked improvement in selectivity for cod (Frandsen et al., 2009).

A first step in developing a new window to change the gear selectivity and thereby decrease cod catches in the Norway lobster fishery was tested by Madsen et al. (*submitted*). The concepts involved included moving the window further back; adding more stability to the codend to avoid loss of Norway lobster through the window; making the section where the window is located relatively narrow; and using larger mesh sizes (300 mm) in the window than those currently in use.

This paper presents the second step in our research: developing and testing a window concept that can be commercially used and is simple to install and control in the different trawl designs used in the Kattegat Norway lobster. A further goal of the development work was to find a flexible solution that makes the selectivity of a window adjustable according to a particular need. A final aim of the present work was to compare the selectivity of the sorting box with the selectivity of a conventional diamond mesh codend.

Materials and methods

The sorting box concept and the standard codend

The basic principle of the sorting box concept is to improve and control the gear's selectivity for cod without influencing the selectivity and catch efficiency of Norway lobster. The development of the new concepts is described in more detail in Madsen et al. (*submitted*). The main principles are to move the window as far back as possible to improve the release of cod but still prevent the accumulating Norway lobster catch from coming into contact with the window; to situate the window in a relatively narrow four-panel section, which will ensure a stable performance and good control of up and down orientation; to place the window in a relatively narrow section in order to reduce the escape route length; to use larger mesh sizes in the window than those currently in use; and to make the selectivity adjustable according to the current need to protect cod stocks.

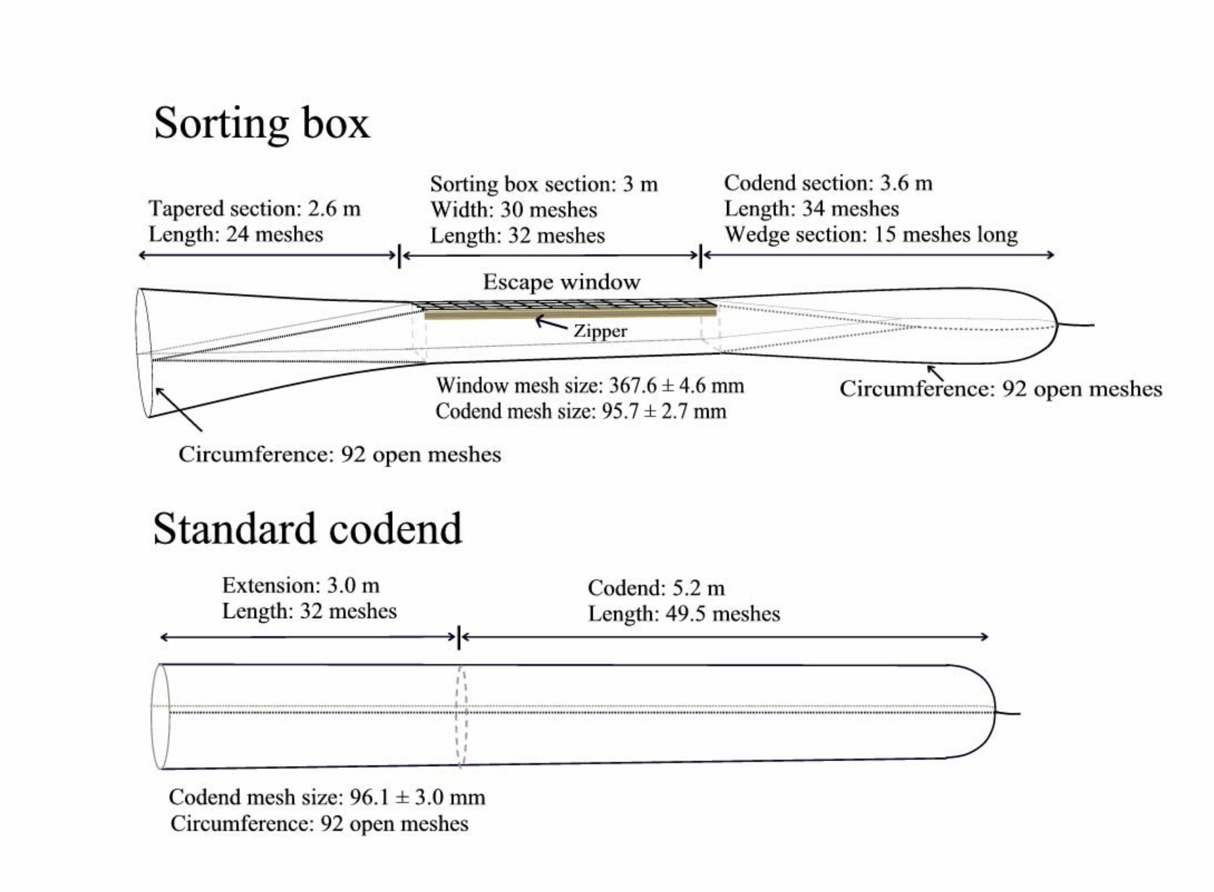

Figure 1. Illustration of the sorting box tested in the second sea trial. Distances are given in open meshes and stretched lengths. Measured mesh sizes are indicated along with the standard deviation.

The sorting box used in these sea trials is illustrated in Figure 1. The mesh size in the window was increased to 400 mm because in previous sea trials (Madsen et al., *submitted*) we observed that some of the largest cod were not able to pass through the 300 mm window. The net in the window was coated polyamide thread produced by Carlsen Net (www.carlsen-net.dk). This netting is well tested for use in square mesh windows. The coated twine was white, which should reduce the visual contrast between the meshes in the window and light from above (Glass et al., 1993). The window was fastened to the codend on each side with a 3 m long zipper (Figure 1); at the forward and aft end, the window was joined to the codend with thread. This is a flexible solution that allows the selectivity to be adjusted according to the present need by quickly (about 10–15 min) replacing the window with another mesh size. Except for the window, the codend was made of nominal 90 mm double twine 4 mm PE netting. This material was chosen because it is commercially used and thus makes comparisons with a conventional standard codend easier. A 3 m long leaded rope (1 kg/m) was attached to each of the lower selvedges in the four-panel section because in flume tank tests the sorting box shape was more unstable (less stretched) with stiff double twine than with the single twine used in the initial experiments (Madsen et al., *submitted*).

A conventional 90 mm standard diamond mesh codend made of the same type of netting as the sorting box (4 mm PE netting) was used for comparison (Figure 1). The 90 mm mesh is the minimum legal mesh size and the preferred mesh size of most of the Kattegat fleet. Until about 2 years ago this codend was specified in the legislation for the area. Today legislation requires that it be equipped with a 120 mm window. We used a codend without a window to avoid an extra parameter in the comparisons. Furthermore, Frandsen et al. (2009) found no statistical significant ($p < 0.05$) difference between 90 mm codends with and without the 120 mm window.

Sea trials and data collecting

A commercial stern trawler (RS30, Mette Amalie, 386 kW, 20 m length) was used to conduct two sea trials in August 2007. It was rigged for twin trawling with two identical combined fish- and Norway lobster-trawls fishing simultaneously. The trawls have a circumference of 460 meshes and a nominal mesh opening of 100 mm. A three-warp towing system with a 550 kg chain clump and two 194 cm Welle otter boards was used to tow the gear. Each codend was tested on each sea trial on one side of the twin trawl rig; the other side of the twin trawl rig was dedicated to other experiments that will be reported elsewhere.

Data for estimation of the selectivity of the codends were obtained using the covered codend methodology (Madsen et al., 2001). To limit the visual contrast, the cover netting in the region around the codend was made of knotted thin (1.2 mm) white nominal 40 mm Dyneema twine mounted in a square mesh configuration. The aft part of the cover was made of PE netting (1.8 mm) with a nominal mesh opening of 40 mm. A combination of kites, chains, and floats were used to keep the covers from touching or blocking the meshes of the test codends (Madsen et al., 2001). A zipper in the side of the cover provided easy access to empty the codend. To obtain the total catch weight, the entire codend and cover fraction was weighed using a crane scale on deck, and then the weight of the netting was subtracted. Length measurements were focused on cod, plaice (*Pleuronectes platessa*), and Norway lobster, which are the most important commercial species in this fishery.

All cod were measured. In a few cases with very large catches, only subsamples of plaice were measured. Length of other commercial fish species caught by the sorting box was recorded because they have some influence on economy. In cases in which a minimum landing size (MLS) exists, only individuals above the MLS were measured. However, very few of these species under the MLS were observed. Fish were measured to the nearest cm. A subsample of the catch of Norway lobster in most hauls was measured to the nearest mm with an electronic calliper. The midpoints of the length classes of fish and Norway lobster were used in the subsequent analysis. Mesh sizes were measured with the OMEGA gauge (Fonteyne et al., 2007).

Statistical modelling and analysis

Statistical modelling was conducted on the catch data for cod, plaice, and Norway lobster. These are the economically most important species caught in reasonably high numbers in most hauls. The analysis followed Madsen et al. (*submitted*) and Frandsen et al. (2009) and the approach is briefly recapped here.

Cod retained in the codend of the sorting box potentially were exposed to two selective mechanisms represented by the sorting box window and the codend. This leads to the following composite effective selection curve:

$$\varphi(\ell) = [1 - \gamma \cdot (1 - r_{window}(\ell))] \cdot r_{codend}(\ell), \qquad (1)$$

where $r_{window}(\ell)$ and $r_{codend}(\ell)$ denote the proportion of length ℓ cod retained by the window and codend, respectively, given that they have been in contact with the window/codend. Furthermore, γ denotes the proportion of fish that enters the codend and comes into contact with the window. We used logistic curves to model $r_{window}(\ell)$ and $r_{codend}(\ell)$.

The selectivity for cod, plaice, and Norway lobster in the standard codend and Norway lobster in the sorting box with a 400 mm window were modelled by a logistic function (Wileman et al., 1996). Goodness of fit for individual hauls was assessed by deviance residuals and the deviance statistic (McCullagh and Nelder, 1989) and suggested that the logistic function in general provided a good fit. It was noted that there was a high variation between hauls for Norway lobster.

The catch data for plaice in the sorting box suggested a bell-shaped effective retention curve. This reflects the product of an ascending codend selection and descending window absorption. Among the normal, the log-normal, and the gamma curves (Frandsen et al., 2009), the normal curve:

$$r(\ell) = \omega \cdot \exp\left(-\frac{(\ell - \ell_0)^2}{2\sigma^2} \right) \qquad (2)$$

provided the best fit in terms of smallest deviance. Here, ℓ_0, σ, and ω are the modal length, the spread, and the modal value, respectively. See Frandsen et al. (2009) for further details.

It was not possible to obtain convergence for all individual hauls. Consequently, the use of Fryers model for between-haul variation (Fryer, 1991) would necessarily be constrained to a subset of the data. This might potentially lead to biased estimates. Instead, we used the SELECT method on the set of all hauls stacked into a single data set (Millar et al., 2004; Frandsen et al., 2009). Standard errors were adjusted for overdispersion according to Wileman et al. (1996). Tests for differences between the two codends were based on Walds test.

We estimated a theoretical selection curve for the 120 mm standard codend that has been used in the North Sea since 2002 (Madsen and Stæhr, 2005) to improve selectivity of cod, as this mesh size has been considered as an option in the Kattegat and Skaggerak (Krag et al., 2008). We used the selectivity estimates of the standard codend and extrapolated by assuming that the selection factor (SF = $\ell_{50\%}$ / mesh size) and the selection ratio ($SR/\ell_{50\%}$) are constant.

Results

A total of 11 hauls were conducted with the sorting box and 16 hauls with the standard codend. Operational conditions are provided in Table 1. Measured mesh sizes (wet condition, N indicates number measured) of the sorting box codend (N = 200), the window (N = 50), and the standard codend (N = 300) are indicated with standard deviation in Figure 1.

Table 1. Operational conditions during the sea trials. Average (avg.) per haul with standard deviation (SD).

Codend	No. hauls	Haul duration (hrs)	Depth (m)	Speed (kts)	Codend catch (kg)
Sorting box	11	3.27 ± 0.18	64.4 ± 33.8	2.8 ± 0.28	147 ± 219
Standard codend	16	3.58 ± 0.79	52.0 ± 31.9	2.6 ± 0.11	218 ± 132

Table 2 provides detailed information on total catches of cod, plaice, and Norway lobster above and below the MLS. The retention of cod both below and above the MLS in the sorting box was very low; values were about 6 and 8 times higher in the standard codend. Almost all plaice above the MLS were retained in the standard codend, whereas only 8% were retained in the sorting box. The sorting box also retained about five times fewer plaice below the MLS. About 10% fewer Norway lobster above the MLS were retained in total in the sorting box compared to the standard codend, and the difference was larger for Norway lobster below the MLS.

Table 2. Total cod, plaice, and Norway lobster entering and retained for the sorting box and standard codend. Species are divided according to MLS where UMLS indicates under minimum landing size. Cod MLS = 30 cm, plaice MLS = 27 cm, and Norway lobster MLS = 40 mm carapace length.

	Cod			Plaice			Norway lobster		
	UMLS	MLS	Tot	UMLS	MLS	Tot	UMLS	MLS	Tot
<u>Sorting box</u>									
Entering (no.)	1156	1942	3098	2469	209	2678	24701	4090	28796
Retained (%)	6.5	10.4	8.9	4.9	8.1	5.2	39.9	72.0	44.4
<u>Standard codend</u>									
Entering (no.)	444	333	777	2984	263	3247	19832	3942	23826
Retained (%)	40.8	84.2	58.2	27.8	99.6	32.1	68.8	82.4	71.1

Table 3 shows data for other commercial species for which more than seven individuals above the MLS were caught. Saithe (*Pollachius virens*) were caught in a reasonable quantity, and a very low retention was observed. A very low retention of witch also was observed, whereas ~40% retainment was observed for brill (*Scophthalamus rhombus*) and sole (*Solea solea*). However, very few sole were caught.

Table 3. Catches of other species. Total entering and retained for the sorting box. Saithe, brill and sole above MLS. There is no MLS on witch.

	Sorting box	
Species	Entering (no.)	Retained (%)
Saithe $\geq$ 30 cm	455	5.1
Witch, all sizes	49	4.1
Brill $\geq$ 30 cm	47	38.3
Sole $\geq$ 24 cm	7	42.9

Table 4. Estimated selectivity parameters with the standard deviation in brackets. Degrees of freedom (DF) and deviance (DEV) are indicated.

Sorting box		Standard codend	
Species and model	Estimate	Species and model	Estimate
Cod		*Cod*	
$\ell_{50\%}$, codend (cm)	18.1 (4.97)	$\ell_{50\%}$ (cm)	23.9 (0.63)
SR, codend (cm)	20.1 (8.95)	*SR* (cm)	14.5 (1.4)
$\ell_{50\%}$, window (cm)	101.2 (10.1)	DF	288
SR, window (cm)	15.7 (12.1)	DEV	334
γ	0.890 (0.020)		
DF	414		
DEV	417		
Plaice		*Plaice*	
ℓ_0 (cm)	26.6 (0.652)	$\ell_{50\%}$ (cm)	21.8 (0.12)
σ (cm)	3.97 (0.352)	*SR* (cm)	3.3 (0.17)
ω	0.293 (0.0518)	DF	611
DF	157	DEV	319
DEV	191		
Norway lobster		*Norway lobster*	
$\ell_{50\%}$ (mm)	25.1 (2.9)	$\ell_{50\%}$ (mm)	28.9 (1.5)
SR (mm)	36.7 (9.5)	*SR* (mm)	34.7 (6.8)
DF	320	DF	426
DEV	1625	DEV	2181

Selectivity parameters of cod, plaice, and Norway lobster caught in both codends are provided in Table 4. The estimated proportion of cod that came into contact with the window of the sorting box (γ) was very high, which means that the cod had a good chance to escape. The $\ell_{50\%}$ of Norway lobster in the sorting box was lower than that in the standard codend, whereas the *SR* was higher. However, these differences were not significant ($p > 0.05$). Relatively large standard errors of *SR* and a high model deviance compared to degrees of freedom were found.

The resulting selection curves of the sorting box and the standard codend are compared in Figure 2. The difference in the shape of the curve for cod and plaice is very apparent, whereas for Norway lobster it appears to be small above the MLS (Figure 2). The theoretical selection curve for a 120 mm codend shows that the selectivity of cod is considerable less compared to the selection curve of the sorting box, whereas the selectivity for Norway lobster is higher than for the sorting box.

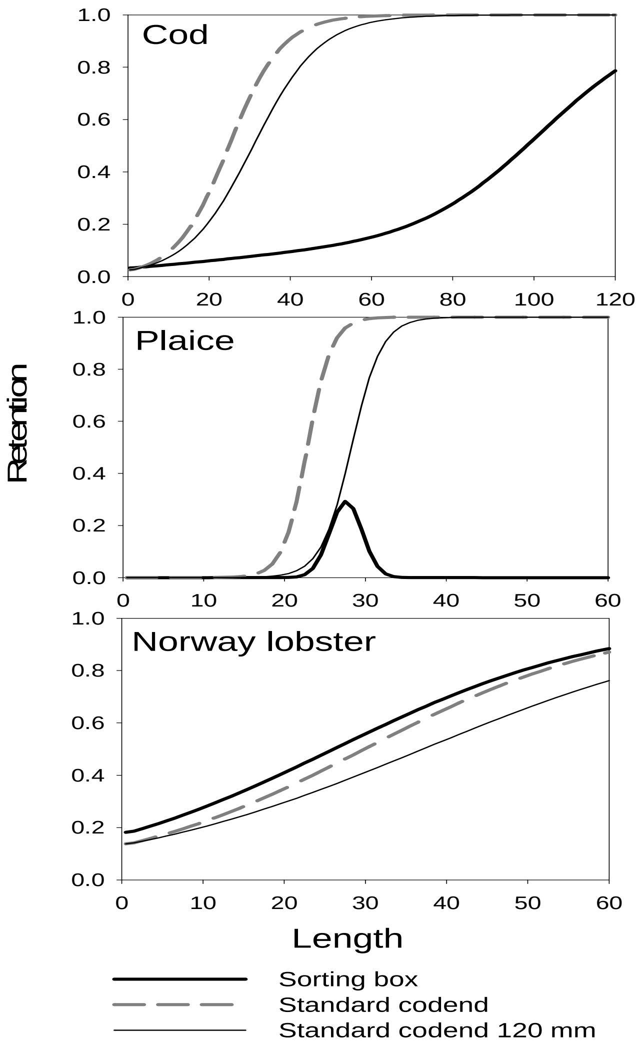

Figure 2. Retention for the sorting box, the tested standard codend, and a theoretical curve for a standard 120 mm codend. Length in cm for cod and plaice and mm carapace length for Norway lobster.

Discussion

The selectivity of the 120 mm window implemented in the Kattegat fishery today is not satisfactory (Frandsen, 2009) considering the need for rebuilding of the cod stock. Our experiments are promising since they clearly demonstrated that our design concept could substantially improve the gear selectivity to let cod escape. A very high proportion of cod come into contact with the window, which agrees with results of initial experiments with the sorting box concept (Madsen et al., *submitted*). In contrast to a grid, the window depends on active escape behavior. All experiments were conducted during the summer and during the day; cod may react differently at night (Krag et al., *in press*) or when the water temperature is lower and swimming performance is reduced (He, 1993). The improvement in gear selectivity with respect to releasing cod that can be attained by increasing the mesh size to 120 mm, as used in some North Sea consumption fisheries, is limited compared to the improvements provided by the sorting box, and the former will reduce the catch of Norway lobster above MLS by about one third (Krag et al., 2008). Compared to the estimates for a 35 mm grid (Frandsen et al., 2009), the retention small cod was considerably lower (about 20%) in the sorting box. For larger cod (> 30 cm), the selectivity in the sorting box was lower compared to the grid, which will reject almost all cod above a given size (Catchpole et al., 2006; Valentinsson and Ulmestrand, 2008; Frandsen et al., 2009). Inserting a window by a zipper was a simple way to the selectivity adjustable according to given needs which worked well. The high proportion of cod that comes into contact with the window offers the possibility of adjusting the selectivity for cod in cases where it is allowed or desirable to retain the cod catch.

Although the sorting box retained about 10% fewer Norway lobster above MLS than did the standard 90 mm codend, the selection curves were comparable and no statistically significant difference ($p > 0.05$) was found in selectivity parameters. There was a high variation between the hauls, which was indicated by relatively large variances and by deviance residuals. The codends were not fished at the same time in equal conditions, and in general considerable variation between experiments is observed for Norway lobster (ICES, 2007). Due to the different designs of the codends, the selective properties of the diamond mesh netting in the sorting box might differ from those of the standard codend. It is important to assess this matter further to reduce the possible loss of Norway lobster as much as possible, thereby making the fishery targeting Norway lobster economically viable.

A very large escape rate of plaice was observed, and this result was similar to reported in the initial experiments (Madsen et al., *submitted*). We have found that the vertical distribution of plaice is relatively even in the aft end of a trawl (Krag et al., 2009) and that plaice seems to actively seek escape through the window. The results for brill indicate that other flatfish species might behave differently. It is important to gather more data on sole because it is an economically important species in the Kattegat. Whether it is possible to develop the concept further to increase the retention of flatfish should be investigated.

A very selective Norway lobster grid (Valentinsson and Ulmestrand, 2008) has been a legal alternative for the Danish fleet operating in Kattegat and Skagerrak since 2005 and vessels using the grid are rewarded with unlimited days at sea. However, not a single Danish vessel is using the grid today due to the loss of fish and Norway lobster in general and the handling difficulties associated with rigid structures such as grids. The sorting box system can substantially reduce the catch of cod while maintaining a high retention of Norway lobster. The design is easy to handle and at the same time very flexible; it can quickly be adjusted according to the catch composition on the fishing grounds or according to the single vessels specific quota rights (on cod, for example). The concept is rather universal and can be used in other areas (*eg.* North Sea, Irish Sea and Skagerrak) and fisheries, where similar problems exist.

A modified version of the sorting box was implemented in the Kattegat as a bilateral agreement between Sweden and Denmark as an alternative to a sorting grid, to be used in areas and spawning seasons when catchability and landings of cod are high. We are continuing the work on assessing and improving the performance of the sorting box concept.

Acknowledgement

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